# DESIGN AND DEVELOPMENT OF DISCRETE LASER DIODE DRIVER

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#### ABSTRACT

Laser diode power supplies are power supplies that are required to provide a constant current output to the laser diode. Due to the dynamic LI characteristic of the laser diode, the control of current in the laser circuit is very complicated. The characteristic of laser diode defines a threshold current and a maximum current between which the current has to be fixed. The complicating aspect of this is that this range is just 10-20% of the threshold value. A power supply circuit for laser diodes, in general should account to numerous features. The features of the diode power supply can be classified on the basis of two factors, firstly its performance issues and secondly its protections issues. Performance and protection are the basic concerns for laser current sources. Performance issues include the current source's magnitude and stability under all conditions, output-connection restrictions, voltage compliance, efficiency, programming interface, and power requirements. Protection features are necessary to prevent laser and optical component damage. The laser, which is an expensive and delicate device, must have protection under all conditions, including supply ramp-up and -down, improper control-input commands, open or intermittent load connections etc. A circuit that provides all the fundamental features is being done here.

KEYWORDS: Laser diode, current driver, simulator, CAD, operating current.

# I. Introduction

Lasers, ever since its invention in the 1960s have proven to be one of the most powerful and efficient optical devices that have found its application in almost all technological fields. High coherence and mono-chromaticity are the major advantages of lasers. DC current is the power source for a large group of fiber-optic lasers. A current source with modulation farther along the signal path supplies laser drive. The current source, although conceptually simple, constitutes a tricky design problem. A number of practical requirements have to be considered and failure to do so can destroy lasers or optical components.

A laser current source is deceptively simple in concept. Laser current is the sole output. In practice, however, a laser current source must meet a number of subtle requirements. The key to successful design is a thorough understanding of individual system requirements. Various approaches suit different sets of freedoms and constraints, although all must address some basic concerns. Performance and protection are the basic concerns for laser current sources.

The aim is to design and implement a reliable and cost-effective circuit for laser diode power supply that meets all the space and protection requirements of the laser diode and has output power stability over full voltage and temperature range.

# II. SIMULATIONS

Before letting the circuit done and burn its own, it is wise to check its performance in simulators. We have employed Pspice as the circuit simulator. Here the circuit has to drawn with parts in its component library and has to be assembled as in the circuit. One of the challenges that we came across was the usability of the simulator since it doesn't support as high as 88 nodes. It supports only

to a maximum of 64 nodes. So we decided to break the circuit into various fragments and integrate it later to complete circuit. In fact this approach is said to be modularity which has many other side gains. We have brought about two simulated prototypes with its results verified in the Pspice. The experiment and the screen shot of the result is described in the next section.

# 2.1) Desired Characteristics

While working to build an independent circuitry our first and foremost thing in the mind was to fix the desired characteristics. Although the LI characteristic is smoothly explained in the previous section, life is not so easy when we take it to practical experiments. The desired characteristic is shown in the figure. Our aim can be presented in a sentence at this point. To control the output current in accordance with the input voltage that is given by the user. Hence to fix the output current by controlling the input voltage of an operational amplifier circuit is desired for the easiest establishment of the desired characteristics.

The output current should increase as seen in accordance with the input voltage. But not a linear increase, we have to track two checkpoints. Firstly the threshold current and then the preferred value of current. The threshold current detection is not so easy. This is more difficult with the fact that although theory deals with a constant value for any diode, in practice the manufacturers prescribe a range of value for the threshold. For example, the diode that we use has a threshold value between 18-25mA. The detection of the threshold current and controlling the current henceforth with cautious eyes becomes the major part of the work. The preferred current is to be designed well below the maximum current prescribed by the manufacturer.

#### 2.2) Use of laser Diode Module

The diode module which is employed is a combination of laser diode and a photo detector. The photo detector senses the light emitted by the laser diode and an effective current of .2mA can be drawn through the device. It is interesting to note that the laser emits light only after it gets the threshold current. Hence employing the photo detector eases the task of finding one of the checkpoints. Also, the threshold variation that may occur due to the changes in environmental actions is compensated by the use of photo detector in association with the laser diode, simply put as laser diode module. The current through the photo detector increases proportional to the light output of the laser diode. The detector has the maximum current through it when the light emitted is maximum. In other words, this happens when the maximum current that can be applied to the device occurs. Hence the second checkpoint is also located. But it is imperative to note that with an ordinary feedback mechanism, this increase can't be sensed as it takes place in a very short interval of time. Now it makes enough sense why the slope of the characteristic curve is decreased after the first checkpoint is detected.

#### 2.3) Simulation 1- Current Drive

The first circuit that we have simulated is the basic current drive circuit. We have employed a comparator and a series pass transistor as seen in the circuit. At this stage, it is inevitable to say a few words about a comparator based on operational amplifier. A comparator is a device that accepts two levels of input signal. One of the signals would be a reference voltage level and the other is the input voltage that has to be compared. A comparator circuit has only two output voltage levels. They are the saturation level, either positive saturation voltage or the negative saturation voltage. The saturation voltage level is fixed by the operating voltage of the comparator IC package. When the reference is given to the inverting terminal of the operational amplifier, with the test voltage applied to the non inverting terminal, whenever the voltage level increases above the reference level, the output becomes positive saturation. Otherwise, the output would be negative saturation level. When the device is configured in the opposite manner, the output naturally follows the opposite way. Although the comparator characteristics take a non linear graph, it is mandatory to assume that switching is ideal. The series pass transistor is a switching transistor. It becomes ON when there is a base current while it can be considered OFF when the base current is absent. As seen in the figure, the OPAMP has input test signal at the non inverting terminal and the reference level is fixed in accordance with the output level at the inverting terminal. The series pass transistor has its base connected the output of the

OPAMP. The resistor R5 can be treated as the laser diode under simulation. Resistance R2 is the sense resistor.

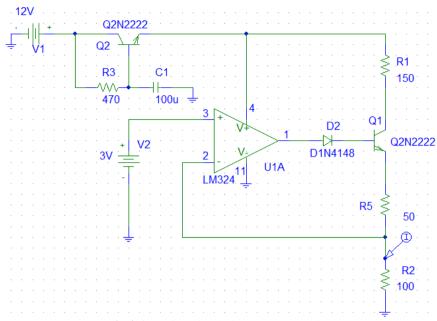


Fig.2.1 Pspice Simulation I- current drive

The design of the circuit is performed considering the fact that the working potential for the laser diode is 2V, Vce of the transistor is 0.3V and the reference level is fixed at 3V. Also 3V is given to the non inverting terminal of the OPAMP. Considering a stage at which the output of OPAMP having positive saturation voltage, the circuit working can be dealt in the following manner. The positive saturation voltage forwards biases the signal diode and hence establishes an effective current through it. This forms the base current sufficient to drive the transistor to saturation. This would introduce a current through R5 and R2. The drop across R2 sets the reference level.

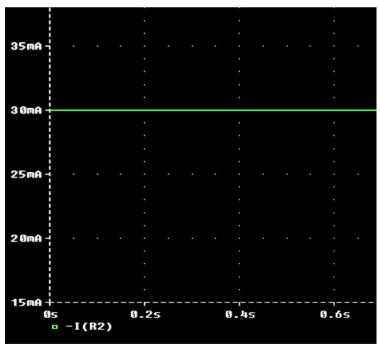


Fig. 2.2 Pspice simulated output showing transfer characteristics

The circuit design maintains the voltage at inverting terminal well below the switching voltage. In any situation if the voltage increases due to the increase in the current through R5, the comparator output voltage switches to negative saturation voltage. This switch OFF the series pass transistor and hence

the output current drops. And now the voltage across R5 is set below the voltage at the non inverting terminal bringing the output to the previous level of positive saturation voltage. However these takes place in negligible time interval making the output current constant at the operating levels as seen in the output characteristics curve.

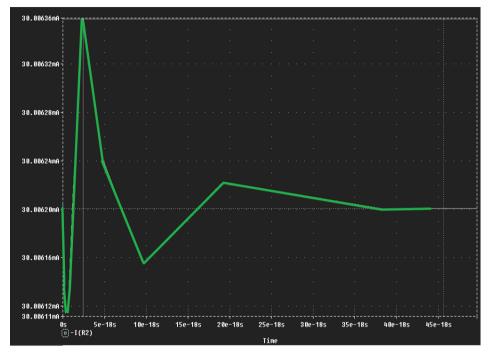


Fig.2.3 Pspice simulated output showing the progress of output current with respect to time.

### 2.4) Simulation Circuit II- Current Block

The second circuit that we have tested in the simulator is the current block circuit. From the discussions in the theory section, it is clear that the output current should not be allowed to rise above the maximum level. So a preferred value of the current has to be fixed which is well below the maximum level prescribed by the manufacturer. The output current should not be allowed to rise above that. This is done by employing a current block circuit as seen in the figure.

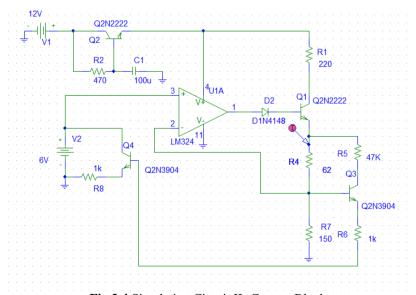


Fig 2.4 Simulation Circuit II- Current Block

The additional circuit that is used here is idle when the current is below the normal operating current. However when the current rises above the limits, that is reflected in the output as an increased drop across the resistor R5. This would forward bias the transistor Q2. In consequence, the transistor Q3 is also switched to saturation. Assuming that the transistor is a closed switch when at saturation, it virtually shorts the input voltage at the non inverting terminals and hence a reduced input voltage is set up at the non inverting terminal that brings down the output current.

The design of the circuit is performed in accordance with the voltage equivalent of the maximum current that can be handled at the input. A voltage slightly lower than this set as the input voltage to act as the input voltage when the current rises above the upper limit.

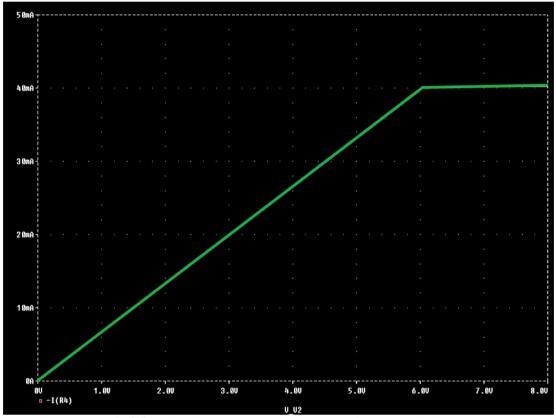


Fig.2.5 Pspice simulated output showing transfer characteristics

# III. BLOCK DIAGRAM AND CIRCUIT DIAGRAM

The circuit can be easily understood dividing it into various blocks. In fact this approach called modularity is one of the common approaches that are adopted to realize complex microelectronics circuits. Reasons to this could be ease of error detecting and correcting, understanding the current bias and operating conditions at various points in the circuit. Also the work can be divided among various hands which could ensure the work done in time restrictions.

The circuit can be fragmented into different the parts as shown in the figure. The current drive provides the operating current required for the laser diode as seen in the characteristics. The current level is regularly monitored by the current sense. It consists of a sense resistor across which the operating current is dropped to extract the voltage level presented. In a parallel manner, the photo detector part of the laser diode mount also monitors the current from which again the voltage level is extracted. The voltage follower in this circuit, presented to the output of the photo detector would increase the voltage level and acts as the second input to the error detector. Also it receives a reference voltage from a zener diode set up. The error detector as a basic comparator does the necessary adjustments to the current given to the laser diode, thus regulating the operating current.

The circuit has provision for soft start and soft decay which adjust the turn ON and OFF behavior of the circuit. Also a temperature sensor is provided which constantly monitors the temperature and switches OFF the circuit when the temperature increases beyond the specified levels.

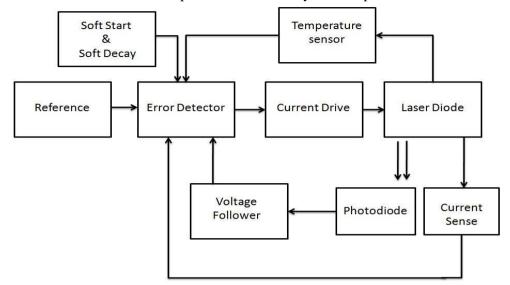


Fig. 3.1 Block Diagram of Laser Diode Driver

# IV. PCB LAYOUT

# 4.1) PCB Layout Designing and Manufacturing

The circuit that is developed after simulation phase is used to build the layout by computer aided design (CAD). Many types of software are available for this purpose; here we have used express PCB as it is easy to use the same. The layout thus designed is printed on a filter paper and is subjected to manufacturing, described in the subsequent section. The best method of constructing any electronic circuit in quantity is to use a printed circuit, stable insulating sheet of material with thin plated copper lines bonded to the sheet forming the circuit path. Although early printed circuits were associated with poor reliability the process of manufacturing board material and providing finished boards now have very few problems.

#### 4.2) Manufacturing

The board material usually comes clad one side with copper. The first step is to drill the holes using a template or automated drilling machine keyed to the full size photopositive from the photo plotter or the Mylar pattern. The hales are then plated through by a tricky multiuse copper plating process, creating continuous conducting paths from one side of the board to the other. The next step is to create tough resist material, adhering to both sides of the board adhering except where the foil for the circuit is to remain. This is done by (a) coating the board with light sensitive film then (b) exposing the board to light with full size photo positive accurately sandwiched on top and (c) chemically developing the film, in precisely the pattern that will ultimately to be removed is immersed into solder-plating bath. The result is to plate solder everywhere that the foil pattern is to remain, including the sides of the hole. Next the resist is chemically, exposing the copper that is to be removed, and the board is treated with copper etching compound. That leaves the desired pattern of the solder plated copper complete with copper plated holes. At this point it is important to carry out a step known as reflow soldering, which consists of heating the board to make the thin solder plating slow. This prevents the formation of tiny layers of metal that could otherwise cause conductive bridges. The next step in board manufacture is to electroplate the edge connector fingers with gold. The final; process in board manufacture consists of applying a solder mask coating over the entire block, covering all areas of the pad areas. This greatly reduces the tendency to form solder bridges between closely spaced traces during subsequent soldering operations. It also makes the board moisture and scratch resistant. Solder mask materials can be applied by silk screen methods (wet masks).

There is a simple process of board manufacturing that is sometimes used, especially in small production situations. In this method begins by coating the board with photo resists, then expose it through a full size negative of desired pattern i.e., a photographic film that is transparent wherever you want foil to remain. The resist is developed and then unexposed resist is dissolved away. This board has a layer of tough resist covering the copper that is to remain, so simply expose it directly to etching compound. After the superfluous copper has been etched away, the remaining resist is washed off with solvent, leaving the desired pattern in copper. At this point it is best to treat the board with an electro less thin plating bath in order to cover the copper with less susceptible to corrosion. As before the edge connector finger will then be gold plated. The final step in this process consists of drilling the holes by hand, using the actual conducting pattern as a guide.

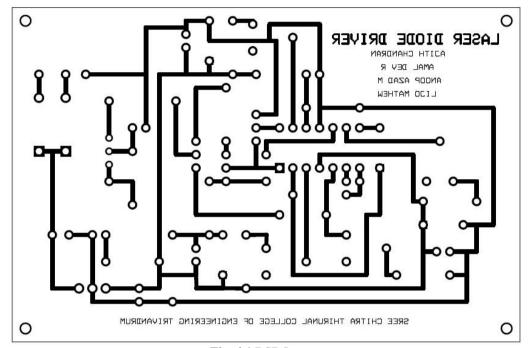


Fig. 4.1 PCB Layout

# V. RESULTS AND DISCUSSION

The diode driver regulates the operating conditions for laser diode of threshold current 20mA and a maximum operating current of 26mA. The stability of the output current is checked for long hours and is proved successful. Additionally, it offers a wide range of temperature to be worked on and detects temperature fluctuations. If the temperature changes beyond the desired limits, the output current is blocked, switching OFF the laser diode. Further the circuit filters noise spikes and rejects the noise amplitudes with accuracy in the range of few micro amperes. The device is enabled with mount that would provide a highly collimated beam of laser. Simplicity is the major attraction in our design. It was been able to built drivers using discrete devices, reducing cost dramatically.

# VI. CONCLUSION AND FUTURE RESEARCH

The laser diode power supply has been a topic of research right from 1980s. The device that we have realized offers the required operating conditions for a desired laser diode and also opens a large window for the development in the future. Laser has been an exemplary invention in the field of optics. It has touched various spheres of scientific world with its indispensable presence. Of these communication fields, it plays an important role when it comes to optical fiber. The laser beam is modulated in accordance with the information voltage to route it to the destination. To modulate the laser beams the driver used should be equipped to work with modulating input voltages. Our device can adapt to modulating input, with minor changes in circuitry, thus glimpsing over the future of optic fiber communication. Secondly, ever since the development of laser diode driver device it has been an

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unbeatable challenge to built a versatile power supply device that would enable to power any laser diode device. It is very pleasing to present that by employing a micro controller based circuit, our device may rewrite the history of laser drivers. So opening a large way to explore in the field of laser diode drivers, we are closing this part of the work.

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